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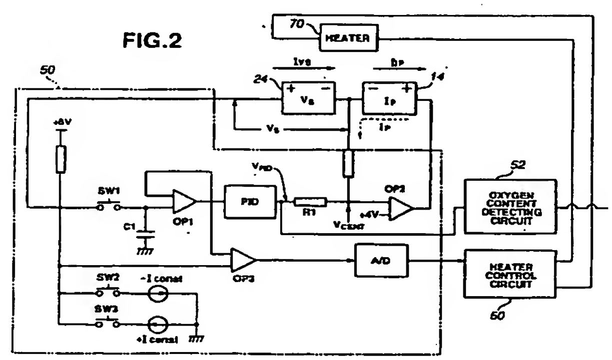
(54) Temperature control for a wide range oxygen sensor

(57) A constant current Iconst is applied to an electromotive force cell which is interposed between a gap (measurement chamber) of a fixed atmosphere and an oxygen reference chamber of a constant oxygen content, for measurement of a resistance value of the electromotive force cell, whereby the resistance value can be measured accurately irrespective of an oxygen content in an atmosphere to be measured by an oxygen sensor element or cell unit. The resistance value of the electromotive force cell is measured at a predetermined timing T2 after application of a current is started, so that a measure resistance value is free of a variation of a resistance value due to deterioration of porous electrodes of an electromotive force cell, such a variation being included in the measured resistance value in case the measurement is done by using an AC current, and therefore accurate measurement can be attained. A temperature control methods and temperature control apparatus for an oxygen sensor, capable of detecting the temperature accurately without suspending measurement of an oxygen content for a long period of time are also provided. Further, a temperature control method and a temperature control apparatus for an oxygen sensor, capable of detecting not only the temperature of the electromotive force cell but the temperature of the pump cell by applying a current or voltage to the electromotive force cell are provided.

FIG.2



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ion conductive solid electrolytic body, and controlling the heater in such a way that the measured resistance value of the electromotive force cell is maintained constant.

By this method, the resistance value is measured by applying a voltage or current to the electromotive force cell interposed between a gap with an atmosphere which is maintained constant by the pump cell and an oxygen reference chamber of a constant oxygen content, so the resistance value can be measured accurately irrespective of the oxygen content in an atmosphere to be measured by the all range oxygen sensor. Further, the resistance value of the electromotive force cell is measured at a predetermined timing or within a predetermined period of time after the application of the current or voltage is started so that a measured resistance value of the electromotive force cell is free of a resistance component at an interface between each of the porous electrodes and the oxygen ion conductive solid electrolytic body. In other words, a varied part of the resistance component at that interface due to deterioration of the interface between the porous electrode of the electromotive force cell and the solid electrolytic body should not be included in the measured resistance value. Such a varied part of the resistance component is included in the measured resistance value in case the measurement is done by using a current or voltage which is applied for a relatively long period of time, i.e., its application and suspension is made at a low frequency or measurement of the resistance is made at a low frequency. The bulk resistance component of the solid electrolytic body of the electromotive force cell can be measured accurately when the predetermined period of time for measurement of the resistance value of the electromotive force cell is set so as to be from 1 μs to 10 ms and more preferably from 1 μs to 1 ms. Accordingly, the resistance value which is accurately reflective of the temperature of the cell can be obtained.

According to another aspect of the present invention, in the above described method, after measurement of the resistance value of the electromotive force cell, a constant current or voltage of a reverse polarity to the constant current or voltage for measurement of the resistance value of the electromotive force call is applied to the electromotive force cell over a predetermined period of time successively to the application of the constant current or voltage for measurement of the resistance value of the electromotive force cell. Preferably, the above described current or voltage of the reverse polarity has the same waveform with the current or voltage for measurement of the resistance value of the electromotive force cell.

In this aspect, at the time of application of the voltage to the electromotive force cell, a constant voltage or current of a polarity reverse to and of the same (i.e. symmetrical) waveform with the voltage or current for measurement of the above described resistance value is applied successively to application of that voltage or current, so it becomes possible to make shorter the reset or restoring time for restoring from condition in which the internal electromotive force of the electromotive force cell is influenced by such an orientation phenomenon of the oxygen ion conductive solid electrolytic body that is caused when a large current is passed through the solid electrolytic body and is incapable of producing an electromotive force reflective of the correct oxygen content difference. Thus, it becomes possible to start measurement of the oxygen content again in a short period of time after measurement of the resistance value, and a high speed control of the all range oxygen sensor can be attained.

According to a further aspect of the present invention, there is provided a method of controlling a temperature of an all range oxygen sensor, the oxygen sensor including a pump cell and an electromotive force cell which are disposed so as to oppose each other with a gap therebetween and which are heated by a heater, the method comprising applying currents or voltages of polarities reverse to each other, to the pump cell and the electromotive force cell at the same time respectively, and measuring a resistance value of the pump cell and/or the electromotive force cell and obtaining the temperature of the oxygen sensor based on the resistance values. Preferably, the currents or voltages of reverse polarities have the same waveform.

By this aspect, the resistance value of the pump cell and/or the electromotive force cell is measured by applying currents or voltages of polarities reverse to each other to the pump cell and the electromotive force cell. The oxygen content in the gap (measurement chamber) which is maintained stoichiometric, tends to vary since pumping of oxygen out of and into the gap occurs when a current or voltage is applied to the electromotive force cell. However, since the current or voltage of the reverse polarity is applied to the pump cell, oxygen is pumped out of or into the gap by the pump cell, whereby pumping in and out are offset to maintain the oxygen content of the gap (measurement chamber) stoichiometric. For this reason, measurement of oxygen by the all range oxygen sensor can be started again immediately after measurement of the resistance value (temperature) is finished.

According to a further aspect of the present invention, there is provided a method of controlling a temperature of an all range oxygen sensor, the all range oxygen sensor including a pump cell and an electromotive force cell which are disposed so as to oppose each other with a gap therebetween and which are heated by a heater, the method comprising detecting internal resistances of both the pump cell and the electromotive force cell.

In this aspect, not only the temperature of the electromotive force cell but the temperature of the pump cell are detected, so even if the sensor itself has a certain temperature distribution or gradient such a temperature

using a current or voltage which is applied and suspended at a high frequency, and the bulk resistance component of the solid electrolytic body of the electromotive force cell can be measured accurately.

According to a further aspect of the present invention, there is provided an apparatus for controlling a temperature of an all range oxygen sensor, the all range oxygen sensor including a pump cell and an electromotive force cell which are disposed so as to oppose each other with a gap therebetween and which are heated by a heater, the apparatus comprising a node connected to a terminal common to a minus terminal of the electromotive force cell and a minus terminal of the pump cell, constant current applying means for applying a current to a plus terminal of the pump cell in a way as to maintain an electric potential at the node constant, a PID circuit having an output terminal connected by way of a resistor to the node for maintaining, by means of a current flowing through the resistor, an electric potential of the electromotive force cell constant, measuring current or voltage applying means for applying a measuring current or voltage for measurement of a temperature of the electromotive force cell to a plus terminal of the electromotive force cell, holding means disposed between the plus terminal of the electromotive force cell and an input terminal of said PID circuit for holding an input potential of the PID circuit constant when the measuring current or voltage is applied to the electromotive force cell by the measuring current or voltage applying means, and measuring means for measuring the electric potential of the electromotive force cell at the time when the measuring current or voltage is applied to the electromotive force cell by means of the measuring current or voltage applying means and measuring the temperature of the electromotive force cell.

By this aspect, when the measuring current or voltage applying means applies a measuring current or voltage to the plus terminal of the electromotive force cell, the hold means disposed between the plus terminal of the electromotive force cell and the input of the PID circuit holds the input voltage of the PID circuit constant and maintains the input potential of the PID circuit constant. For this, the constant current applying means applies a current to the plus terminal of the pump cell in a way as to hold the electric potential at the node which is connected by way of the resistor to the PID circuit. That is, the constant current applying means applies a current or voltage of the polarity reverse to that of the current or voltage applied to the electromotive force cell side, to the pump cell side. In this instance, a current or voltage of polarities reverse to each other are applied to the pump cell and the electromotive force cell at the same time, respectively, to measure the resistance value of the electromotive force cell and/or pump cell. The oxygen content in the gap (measurement chamber) which is maintained stoichiometric, tends to vary since pumping of oxygen out of and into the gap occurs when a current or voltage is applied to the electromotive force cell. However, since the current or voltage of the reverse polarity is applied to the pump cell, oxygen is pumped out of or into the gap by the pump cell, whereby pumping in and out are offset to maintain the oxygen content of the gap (measurement chamber) stoichiometric. For this reason, measurement of oxygen by the all range oxygen sensor can be started again immediately after measurement of the resistance value (temperature) is finished.

According to a further aspect of the present invention, there is provided an apparatus for controlling a temperature of an all range oxygen sensor, the all range oxygen sensor including a pump cell and an electromotive force cell which are disposed so as to oppose each other with a gap therebetween and which are heated by a heater, the apparatus comprising a node connected to a terminal common to a minus terminal of the electromotive force cell and a minus terminal of the pump cell, constant current means for applying a current to a plus terminal of the pump cell in a way as to maintain an electric potential at the node constant, a PID circuit having an output terminal connected by way of a resistor to the node for maintaining, by means of a current flowing through the resistor, an electric potential of the electromotive force cell constant, oxygen content detecting means for detecting an oxygen content based on an output voltage of the PID circuit or an output current of the constant current means, measuring current or voltage applying means for applying a measuring current or voltage for measurement of a temperature of the electromotive force cell to a plus terminal of the electromotive force cell, holding means disposed between the plus terminal of the electromotive force cell and an input terminal of the PID circuit for holding an input potential of the PID circuit constant when the measuring current or voltage is applied to the electromotive force cell by the measuring current or voltage applying means, electromotive force cell temperature measuring means for measuring the electric potential at the plus terminal of the electromotive force cell when the measuring current or voltage is applied to the electromotive force cell by means of the measuring current or voltage applying means and measuring the temperature of the electromotive force cell, pump cell temperature measuring means for measuring an electric potential at the plus terminal of the pump cell and detecting the temperature of the pump cell, and heater control means for less energizing the heater when the temperature of one of the electromotive force cell and the pump cell which is higher in temperature than the other, is higher than a predetermined upper limit value and more energizing the heater when the temperature of one of the electromotive force cell and the pump cell which is lower in temperature, is lower than a predetermined lower limit value.

By this aspect, a common current is passed through the electromotive force cell and the pump cell

sor of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to Fig. 1, an all mode or range oxygen sensor according to an embodiment of the present invention is shown as including a cell unit 10 which is disposed in an exhaust system (not shown). The cell unit 10 measures the oxygen content in the exhaust gases and is connected to a controller 50 for measuring the temperature of the cell unit 10. To the cell unit 10, a heater 70 which is controlled by a heater control circuit 60 is attached by way of an adhesive made of ceramic. The heater 70 is made of an insulation material, i.e., a ceramic material such as alumina and has disposed therewithin a heater circuit or wiring 72. The heater control circuit 60 applies an electric power to the heater 70 in such a way that the resistance of the cell unit 10 which is measured by the controller 50 is maintained constant, whereby to maintain the temperature of cell unit 10 constant.

The cell unit 10 includes a pump cell 14, a porous diffusion layer 18, an electromotive force cell 24 and a reinforcement plate 30 which are placed one upon another. The pump cell 14 is made of solid electrolyte having an oxygen ion conductivity, i.e., stabilized or partially stabilized zirconia (ZrO_2) and has on the front and rear surfaces thereof porous electrodes 12 and 16 mainly made of platinum, respectively. To the front surface side porous electrode 12 which is exposed to the measured gas, a voltage Ip+ is applied for electric current Ip+ to flow therethrough, so the front surface side porous electrode 12 is referred to as an Ip+ electrode. On the other hand, to the rear surface side porous electrode 14, a voltage Ip- is applied for electric current Ip- to flow therethrough, so the rear surface side porous electrode 14 is referred to as an Ip- electrode.

The electromotive force cell 24 is similarly made of stabilized or partially stabilized zirconia (ZrO_2) and has on the front and rear surfaces thereof porous electrodes 22 and 28 mainly made of platinum, respectively. At the porous electrode 22 disposed on a gap (measurement chamber) 20 side, a voltage Vs- is produced by the electromotive force Vs of the electromotive cell 24, so the porous electrode 22 is referred to as a Vs- electrode. On the other hand, at the porous electrode 28 disposed on a oxygen reference chamber 26 side, a voltage Vs+ is produced, so the porous electrode 28 is referred to as a Vs+ electrode. In the meantime, the reference oxygen within the oxygen reference chamber 26 is formed or produced by pumping predetermined oxygen into the porous electrode 28. Between the pump cell 14 and the electromotive force cell 24, the gap (measuring chamber) 20 which is surrounded by the porous diffusion layer 18 is formed. That is, the gap 20 is communicated with the measuring gas atmosphere by way of the porous diffusion layer 18. In the meantime, in this embodiment, the porous diffusion layer 18 formed by filling a porous material in a predetermined place is used but in place thereof pores may be disposed in place.

By this, oxygen according to the difference in the oxygen content between the gas to be measured and the gap 20 is diffused into the gap 20 side by way of the porous diffusion layer 18. In this connection, when the atmosphere within the gap 20 is maintained at a theoretical air-fuel ratio, an electric potential is produced between the gap 20 and the oxygen reference chamber 26 which is maintained constant in oxygen content, i.e., a potential of about 0.45 V is generated between the Vs+ electrode 28 and the Vs- electrode 22 of the electromotive cell 24. In this instance, the controller 50 regulates the current Ip flowing through the pump cell 14 in such a way that the electromotive force Vs of the above described electromotive cell 24 is 0.45 V, whereby to maintain the atmosphere of the gap 20 at a theoretical air-fuel ratio and measure the oxygen content in the gas to be measured, on the basis of the pump cell current Ip for attaining such a theoretical air-fuel ratio.

By additional reference to Fig. 2 that shows the structure of the controller 50, the control actions of the oxygen sensor will be described.

The controller 50 provides an action of measuring the oxygen content by means of the cell unit 10 and an action measuring the bulk resistance of the electromotive cell 24 of the cell unit 10 and thereby measuring the temperature. Firstly, description will be made as to measurement of the oxygen content.

An operational amplifier OP2 has an input terminal to which voltage of +4V is applied and another input terminal which is connected to a Vcent point and operates in a way as to maintain the voltage across the Vcent at 4 V. A PID (proportional integral and differential) circuit that performs a PID control provides an action of detecting an electromotive force Vs of the electromotive force cell 24 and determining the current Ip of the pump cell 14 in such a way that the electromotive force Vs is maintained constant (i.e., at 0.45V) by the effect of the currrent Ip that is made to flow by way of a resistor R1. Thus, under the condition where the electromotive force of the electromotive force cell 24 is maintained at 0.45 V by means of the PID circuit, the voltage V_{PID} that is proportional to the current Ip passed through the pump cell 14 appears at the output terminal of the PID circuit. By means of an oxygen content detecting circuit 52, a corresponding oxygen content corresponding to the voltage V_{PID} appearing at the output terminal of the PID circuit is searched from a map held by the circuit 52, after the voltage V_{PID} being converted to a digital value by means of a A/D (analog-to-digital) circuit (not shown), and the thus searched oxygen content is outputted to the engine control system (not shown) side.

Then, description will be made to the actions of measuring the temperature (resistance) of the electromotive force cell 24, which are provided by the controller 50. An operational amplifier OP1 cooperates with a

force cell 24 and the electromotive force cell 24 is incapable of outputting an internal electromotive force representative of a correct oxygen content difference, a normal condition and for making it possible to start measurement of oxygen concentration again in a short time after measurement of the resistance.

Referring to Fig. 4, description will be made as to the reset time necessary for resetting or restoring of a regular electromotive force which is considered due to an orientation phenomenon of the oxygen ion conductive solid electrolytic body. Fig. 4A shows a variation of the eletromotive force Vs of the electromotive force cell 24 in case a pulsed curent of 4.88 mA corresponding to the above described current -Iconst for measurement of resistance is applied to the electromotive force cell 24 and thereafter the application of current is stopped. Fig. 4B shows a variation of the electromotive force Vs in case a pulsed current of 4.88 mA corresponding to the above described current -Iconst is applied to the electromotive cell 24 and thereafter a pulsed current +Iconst of the reverse polarity to the current -Iconst is applied, i.e., a pulsed current is applied in an alternating manner. As shown in Fig. 4A, in case a pulsed current of 4.88 mA is applied only once, it took 16 sec for resetting or restoring. In contrast to this, in case the current is replaced by the alternating one, resetting or restoring. it took only 0.5 milliseconds for resetting or restoring. In this manner, in this embodiment, a pulsed current is applied in an alternating manner for thereby enabling to start measurement of oxygen content in a short time.

At the timing when the time T4 has lapsed after the lapse of time T3 for application of the constant current + Iconst and after the switch SW3 is turned off, the switch SW1 is turned on to cause the electromotive force Vs of the electromotive force cell 24 to be applied again to the PID circuit by way of the operational amplifier OP1, whereby measurement of the oxygen content is started again. After the lapse of the interval T5, the switch SW1 is turned off, whereby the resistance of the electromotive force cell 24 is measured again.

In this embodiment, the temperature of the cell unit 10 measured by measuring the resistance not of the pump cell 14 but of the electromotive cell 24. The action in this respect will be described with reference to the graphs of Figs. 5A and 5B. Fig. 5A is a graph obtained in case an alternating current is applied to the electromotive force cell 24 side for measurement of the resistance. Fig. 5B is a graph obtained in case an alternating current is applied to the pump cell 14 side for measurement of the resistance. In the graphs, the data were plotted, with the temperature of the heater corresponding to the temperature of the cell unit 10 as ordinate and the measured resistance as abscissa. In this connection, ○ represents the data obtained when measurement was made in the atmosphere of A/F 23 (lean mode) and at the frequency of 20Hz (low frequency), i.e., by using a current or voltage which is applied and suspended at a low frequency, ● represents the data obtained when measurement was made in the atmosphere of A/F 23 (lean mode) and at the frequency of 1 KHz (high frequency), i.e., by using a current or voltage which is applied and suspended at a high frequency, △ represents the data obtained when measurement was made in the atmosphere of the theoretical air-fuel ratio and at the frequency of 20 Hz (low frequency) and ■ represents the data obtained when measurement was made in the atmosphere of the theoretical air-fuel ratio and at the frequency of 1 KHz (high frequency).

From the graph of Fig. 5A that is representative of the data obtained according to the embodiment of the present invention, it will be seen that the resistance measured in the atmosphere of the theoretical air-fuel ratio and the resistance measured in the atmosphere of the lean air-fuel ratio are nearly equal to each other and therefore accurate measurement of the resistance value can be obtained irrespective of the oxygen reference chamber. It is also seen that the measurement at the high speed or high frequency of 1 KHz shows a better result than the measurement at the low speed or low freqency of 20 Hz because of a smaller variation of Rez (resistance) for a given VH (heater voltage). In contrast to this, from the graph of Fig. 5B, it will be seen that the resistance value measured in the atmosphere of the theoretical air-fuel ratio and the resistance value measured in the atmosphere of the lean air-fuel ratio differ from each other and accurate measurement of the resistance value irrespective of the oxygen reference chamber cannot be obtained. This is because the oxygen content on the opposite sides of the electromotive force cell 24 is always constant when the current is applied to the electromotive cell 24 (refer to Fig. 1) since the electromotive force cell 24 is disposed between the gap 20 which has the atmosphere fixed to the theoretical air-fuel ratio and the oxygen reference chamber 26 which is constant in the oxygen content. In contrast to this, the pump cell 14 is disposed between the gas to be measured which varies in the oxygen content and the gap 20 which has the atmosphere fixed to the theoretical air-fuel ratio, so the difference in the oxygen content between the opposite sides of the pump cell always varies depending upon the oxygen content of the gas to be measured.

Referring now to Figs. 7 and 8, another embodiment of the present invention will be described. This embodiment is substantially similar to the previous embodiment described with respect to Figs. 1 to 6 except for a controller 50'. Though the controller 50' has a similar structure to that used in the previous embodiment, it is adapted to provide the following actions which will be described hereinafter.

The controller 50' provides an action of measuring the oxygen content by means of the cell unit 10 and an action measuring the bulk resistance of the electromotive cell 24 of the cell unit 10 and thereby measuring the temperature. Firstly, description will be made as to measurement of the oxygen content.

of the same waveform with the current - Iconst for measurement of the temperature applied to the electromotive force cell 24. In Fig. 8, the electric potential Vp produced by the current of the reverse polarity is shown.

In this embodiment, at the same time when the constant current - Iconst is applied to the electromotive force cell 24 side for measurement of the resistance, a current of a reverse polarity is applied to the pump cell 14 side. In this instance, the oxygen content in the gap (measurement chamber) which is maintained at a theoretical air-fuel ratio, tends to vary since pumping of oxygen out of and into the gap occurs when a current is passed though the electromotive force cell 24. However, since the current - Iconst of the reverse polarity is passed through the pump cell 14, oxygen is pumped out of or into the gap by the pump cell 14, whereby pumping in and out are offset to maintain the oxygen content at the theoretical air-fuel ratio. For this reason, as will be described hereinlater, measurement of the oxygen content by the all range oxygen sensor can be started again immediately after the measurement of the resistance (temperature) is finished or completed.

In this connection, after the lapse of time T2 (i.e., about 60 μs) after application of the current -Iconst is started, the output of the operational amplifier OP3 at that point of time (i.e., at the point of time when 60 μs has lapsed after starting of the application of the current) is outputted to the heater control circuit 60 side after having been converted by the A/D converting circuit from an analog value to a digital value. From such an input or measured value, the heater control circuit 60 grasps or detects the value corresponding to the resistance value of the electromotive force cell 24, i.e., the temperature of the electromotive force cell 24. Simultaneously with the temperature measurement of the electromotive force cell 24, since the current of the reverse polarity to the current -Iconst is flowing through the pump cell 14, the heater control circuit 60 grasps or detects the temperature of the pump cell 14 from the voltage Vp (refer to Fig. 8) produced by the current of the reverse polarity.

In this manner, in this embodiment, by not providing a power source arrangement to the pump cell 14 side for measurement of its temperature but only by making a current flow from the operational amplifier OP1 which is provided for measurement of the oxygen content while by providing a switch SW2 for measurement of the temperature of the electromotive force cell 24, a current of a reverse polarity can be applied to the pump cell 14 side and the temperature of the pump call 14 can be measured at the same time. Further, since in this embodiment the temperatures of the pump cell 14 and the electromotive force cell 24 are measured separately, a temperature increase of either of them can be detected to prevent a malfunction beforehand.

The heater control circuit 60 controls the energizing of the heater 70 in such a manner that the measured value, i.e., the resistance value of the electromotive force cell 24 or pump cell 14 becomes equal to the target value. This control substantially performs such a function of maintaining the temperature of the oxygen sensor element 10 accurately at a target temperature (i.e., 800 °C) by making higher the voltage when the temperature of the eletromotive force cell 24 or the pump cell 14 is higher than a target value and making lower when lower than the target value.

In the meantime, the reason why the value after the lapse of time T2 of 60 μs after the application of the current -Iconst is started is to make the resistance component at the interface between the above described porous electrode and the above described solid electrolyte body be not included in the measured resistance. That is, although a shorter time T2 makes it possible to detect a value closer to the bulk resistance of the eletromotive force cell 24 which is reflective of the temperature accurately, it is set to 60 μs for the purpose of obtaining a sufficient time for a constant current circuit (not shown) for outputting the current -Iconst to become stable after switching of the switch SW2. In other words, measurement is carried out after the lapse of time of 60 μs which is the shortest in view of the circuit structure because if measurement is carried out after a lapse of a certain longer time, it is detected such a value that includes a variation amount of the resistance component at the interface between the porous electrodes 22 and 28 of the electromotive force cell 24 and the solid electrolyte body due to deterioration or the like thereof and therefore due to the variation amount it becomes impossible to carry out accurate measurement. As described hereinbefore, the time T2 can be smaller than 60 μs depending on the circuit structure and preferably ranges from 1 μs to 10 ms and more preferably from 1 μs to 1 ms.

After the lapse of time T3 (100 μs), the switch SW2 is turned off while at the same time the switch SW3 is turned on. In this instance, the reason why the switching time of the switch SW2 is set to 100 μs (T3) is that it takes about 20 μs for the A/S converting circuit to convert the input value which is taken thereinto after the above described lapse of time of 60 μs and a CPU (not shown) switches on the switch SW3 after taking thereinto the data, so the switching time with a margin is set to 100 μs Then, after the switch SW3 is turned on, the constant current +Iconst (+ 4.88 mA) of the reverse polarity to the above described current -Iconst for measurement of resistance is applied to the electromotive force cell 24 side over the time T3 which is substantially the same as that during which the switch SW2 has been turned on.

This is for making shorter the reset time for resetting or restoring, from an abnormal condition in which the internal electromotive force is influenced by the orientation phenomenon of the oxygen ion conductive solid electrolytic body that constitutes the electromotive force cell 24 and the electromotive force cell 24 is incapable of outputting an internal electromotive force

sensor including a pump cell and an electromotive force cell which are disposed so as to oppose each other with a gap therebetween and which are heated by a heater, the method comprising detecting a resistance value of the pump cell and obtaining the temperature of the oxygen sensor based on the resistance value of the pump cell.

2. A method of controlling a temperature of an all range oxygen sensor, wherein the oxygen sensor includes two cells each having an oxygen ion conductive solid electrolytic body and two porous electrodes disposed on opposite sides of the oxygen ion conductive solid electrolytic body, respectively, the two cells are disposed so as to oppose each other with a gap therebetween, one of the cells is used as a pump cell for pumping oxygen out of or into the gap, the other of the cells is used as an electromotive force cell for producing a voltage according to a difference in oxygen content between an oxygen reference chamber and the gap, and the temperature of the two cells is controlled by using a heater, the method comprising:

   applying a constant current or voltage for measurement of resistance value to the electromotive force cell;
   measuring the resistance value of the electromotive force cell within a predetermined period of time after application of said current or voltage for measurement of resistance value in a way that a measured resistance value of the electromotive force cell is free of a resistance component at an interface between each of the porous electrodes and the oxygen ion conductive solid electrolytic body; and
   controlling the heater in such a way that the measured resistance value of the electromotive force cell is maintained constant.

3. The method according to claim 2, wherein after measurement of the resistance value of the electromotive force cell, a constant current or voltage of a reverse polarity to said constant current or voltage for measurement of the resistance value of the electromotive force cell is applied to the electromotive force cell over a predetermined period of time successively to said application of said constant current or voltage for measurement of the resistance value of the electromotive force cell.

4. The method according to claim 3, wherein said constant current or voltage of the reverse polarity has the same waveform with said current or voltage for measurement of the resistance value of the electromotive force cell.

5. The method according to claim 2, wherein said predetermined period of time for measuring the resistance value of the electromotive force cell is from 1 μs to 10 ms.

6. The method according to claim 2, wherein said predetermined period of time for measuring the resistance value of the electromotive force cell is from 1 μs to 1 ms.

7. A method of controlling a temperature of an oxygen sensor for all mode air-fuel mixture, the oxygen sensor including a pump cell and an electromotive force cell which are disposed so as to oppose each other with a gap therebetween and which are heated by a heater, the method comprising applying currents or voltages of polarities reverse to each other, to the pump cell and the electromotive force cell at the same time, respectively, and measuring a resistance value of the pump cell or the electromotive force cell and obtaining the temperature of the oxygen sensor based on the measured resistance value of the pump cell and the electromotive force cell.

8. The method according to claim 7, wherein said currents or voltages of reverse polarities have the same waveform.

9. The method according to claim 7, wherein the resistance value of the pump cell or the electromotive force cell is measured within a period of time after said applying of the currents or voltages, said predetermined period of time being from 1 μs to 10 ms.

10. The method according to claim 7, wherein the resistance value of the pump cell or the electromotive force cell is measured within a period of time after said applying of the currents or voltages, said predetermined period of time being from 1 μs to 1 ms.

11. A method of controlling a temperature of an all range oxygen sensor, the oxygen sensor including a pump cell and an electromotive force cell which are disposed so as to oppose each other with a gap therebetween and which are heated by a heater, the method comprising detecting internal resistances of both of the pump cell and the electromotive force cell.

12. The method according to claim 11, further comprising detecting from the internal resistance of the pump cell and the internal resistance of the electromotive force cell, temperatures of same, respectively and controlling the heater in a way as to less energize the heater when one of the temperatures is higher than a predetermined upper limit value.

a PID circuit having an output terminal connected by way of a resistor to said node for maintaining, by means of a current flowing through said resistor, an electric potential of the electromotive force cell constant;

oxygen content detecting means for detecting an oxygen content based on an output voltage of said PID circuit or an output current of said constant current means;

measuring current or voltage applying means for applying a measuring current or voltage for measurement of a temperature of the electromotive force cell to a plus terminal of the electromotive force cell;

holding means disposed between the plus terminal of the electromotive force cell and an input terminal of said PID circuit for holding an input potential of said PID circuit constant when said measuring current or voltage is applied to the electromotive force cell by said measuring current or voltage applying means;

electromotive force cell temperature measuring means for measuring the electric potential at the plus terminal of the electromotive force cell when said measuring current or voltage is applied to the electromotive force cell by means of said measuring current or voltage applying means and measuring the temperature of the electromotive force cell;

pump cell temperature measuring means for measuring an electric potential at the plus terminal of the pump cell and detecting the temperature of the pump cell; and

heater control means for less energizing the heater when the temperature of one of the electromotive force cell and the pump cell which is higher in temperature than the other, is higher than a predetermined upper limit value and more energizing the heater when the temperature of one of the electromotive force cell and the pump cell which is lower in temperature, is lower than a predetermined lower limit value.

22. The apparatus according to claim 21, wherein said predetermined upper limit value is 900 °C and said predetermined lower limit value is 750 °C.

23. An all range oxygen sensor being provided with the apparatus according to claim 21.

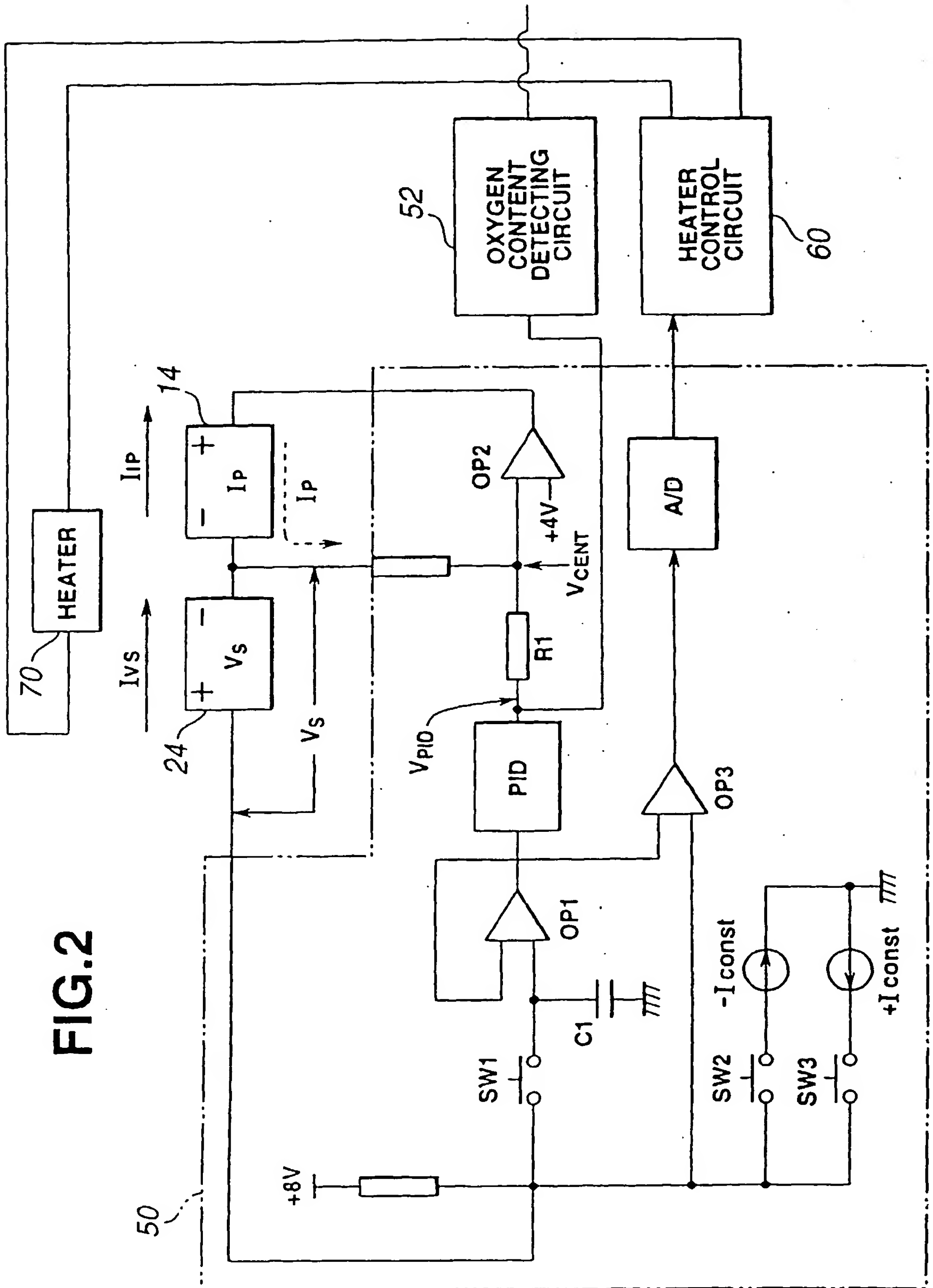

OXYGEN CONTENT DETECTING CIRCUIT
52
HEATER CONTROL CIRCUIT
60
HEATER
70
14
24
IIP
IVS
IP
VS
OP2
+4V
VCENT
R1
VPID
PID
A/D
OP3
OP1
C1
SW1
SW2
SW3
-I const
+I const
+8V
50

FIG.2

FIG.4A

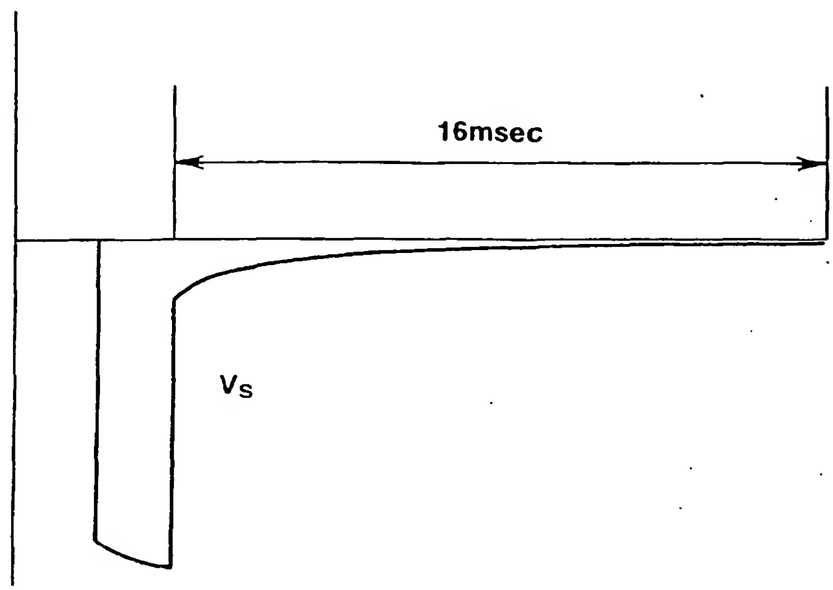


FIG.4B

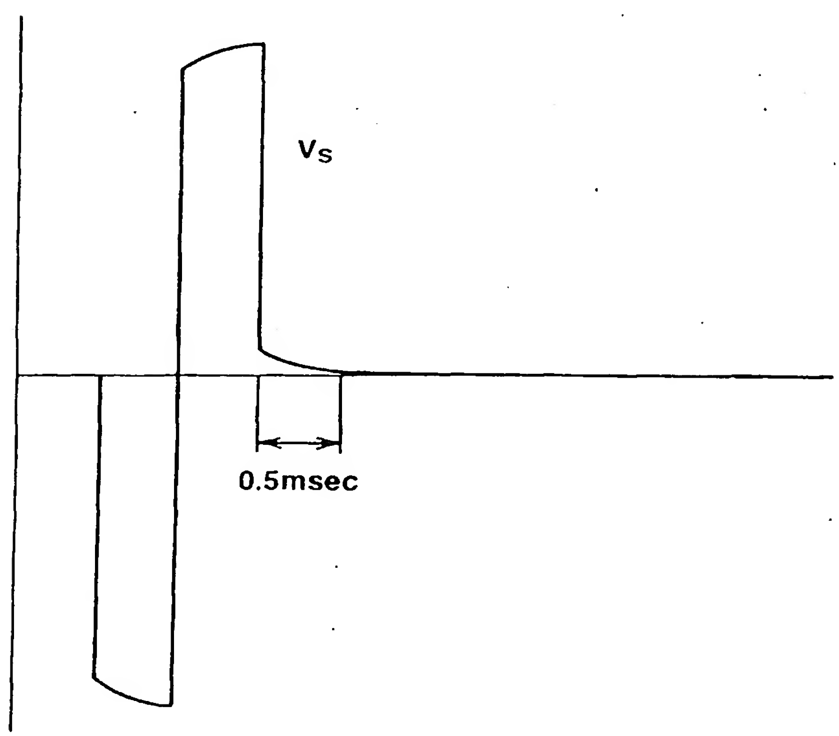


FIG.6

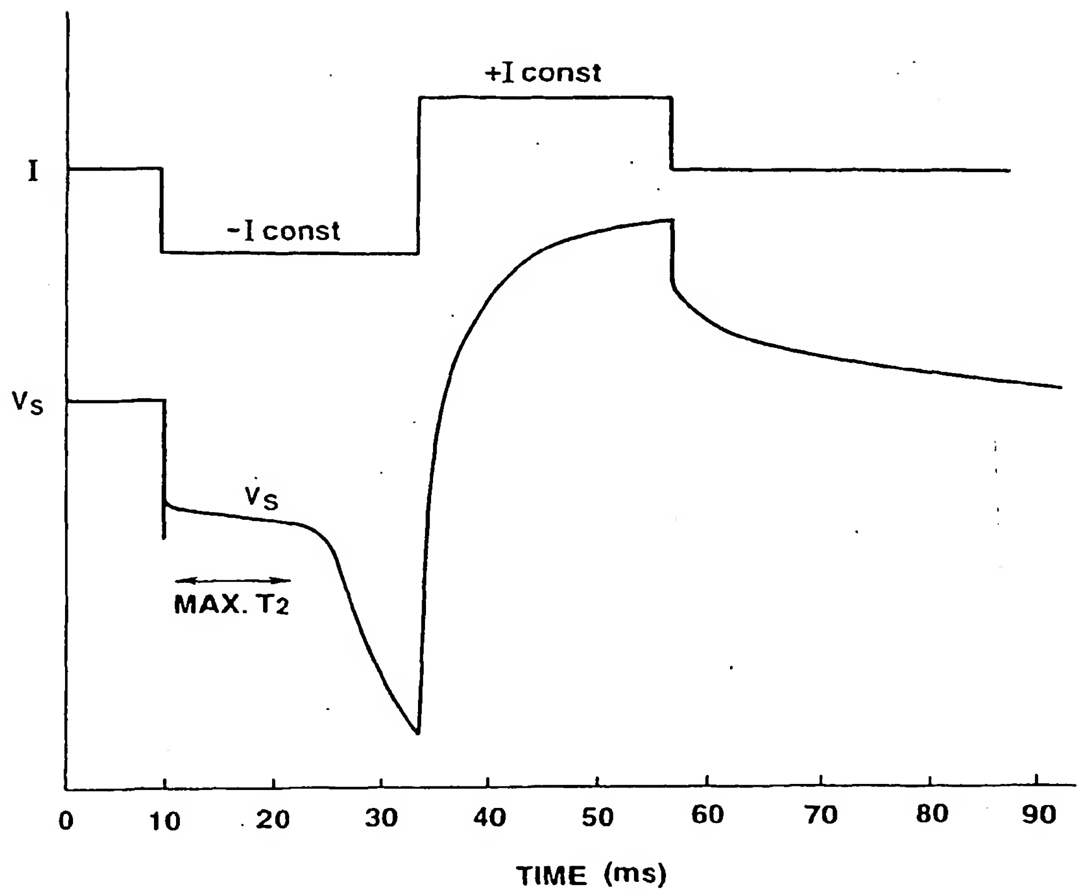


FIG. 8

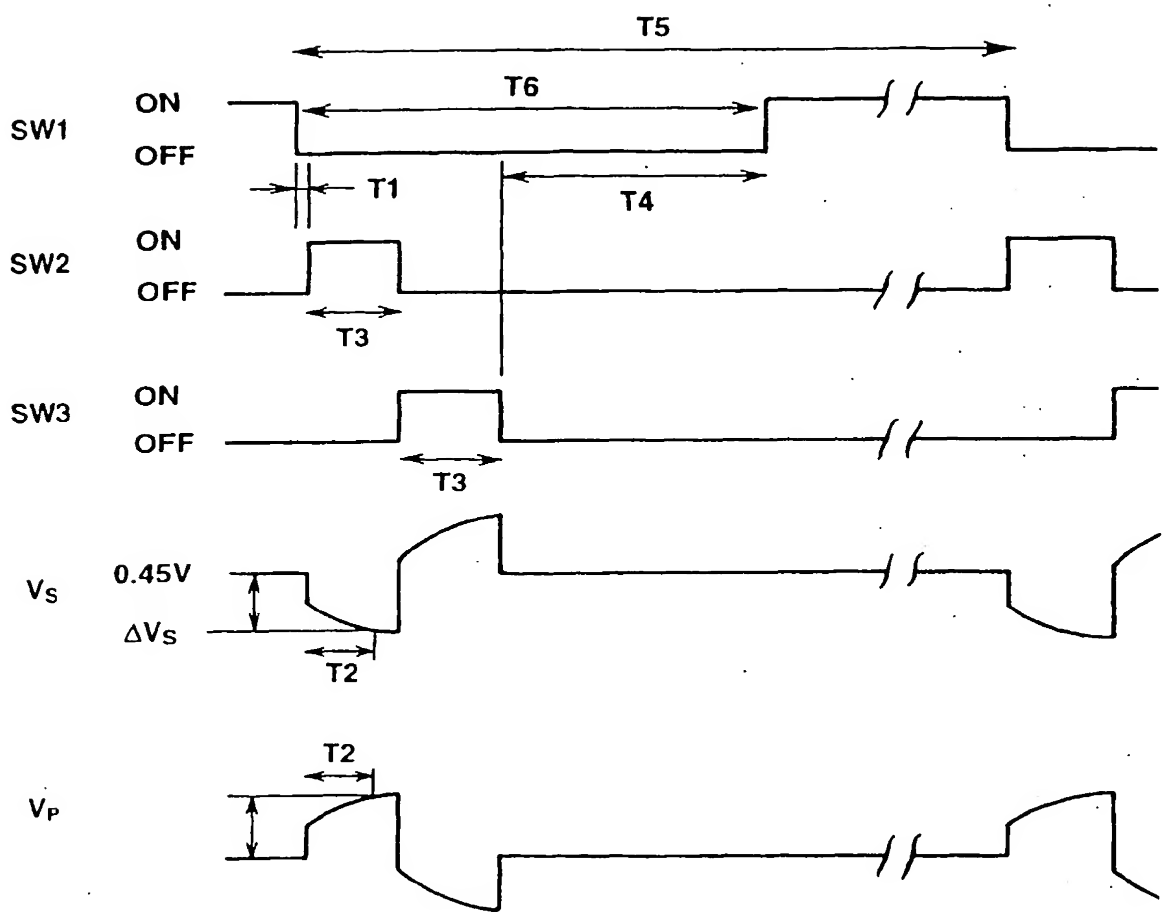
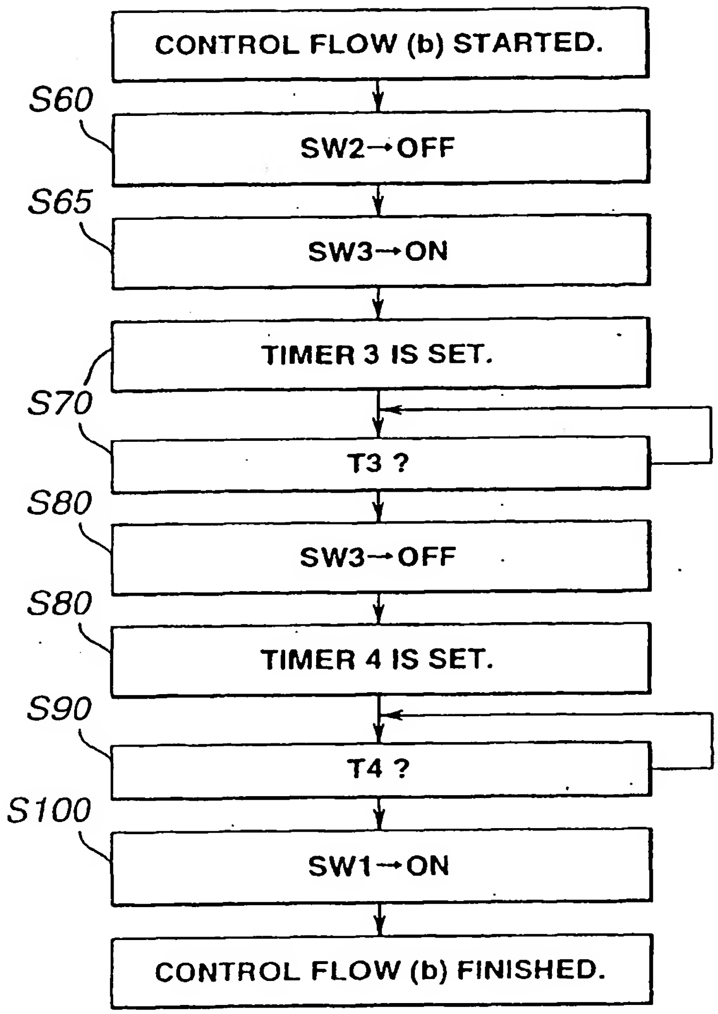

T5
T6
SW1
ON
OFF
T1
T4
SW2
ON
OFF
T3
SW3
ON
OFF
T3
V_S
0.45V
ΔV_S
T2
T2
V_P

FIG.9B


CONTROL FLOW (b) STARTED.
S60
SW2→OFF
S65
SW3→ON
TIMER 3 IS SET.
S70
T3 ?
S80
SW3→OFF
S80
TIMER 4 IS SET.
S90
T4 ?
S100
SW1→ON
CONTROL FLOW (b) FINISHED.

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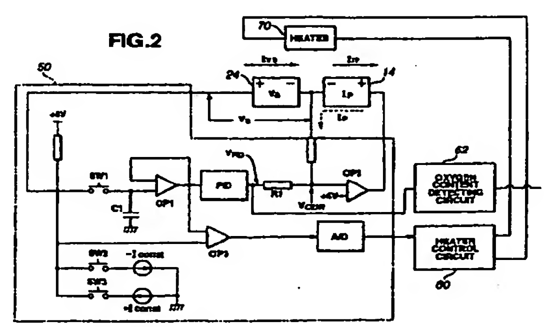
(54) Temperature control for a wide range oxygen sensor

(57) A constant current Iconst is applied to an electromotive force cell which is interposed between a gap (measurement chamber) of a fixed atmosphere and an oxygen reference chamber of a constant oxygen content, for measurement of a resistance value of the electromotive force cell, whereby the resistance value can be measured accurately irrespective of an oxygen content in an atmosphere to be measured by an oxygen sensor element or cell unit. The resistance value of the electromotive force cell is measured at a predetermined timing T2 after application of a current is started, so that a measure resistance value is free of a variation of a resistance value due to deterioration of porous electrodes of an electromotive force cell, such a variation being included in the measured resistance value in case the measurement is done by using an AC current, and therefore accurate measurement can be attained. A temperature control methods and temperature control apparatus for an oxygen sensor, capable of detecting the temperature accurately without suspending measurement of an oxygen content for a long period of time are also provided. Further, a temperature control method and a temperature control apparatus for an oxygen sensor, capable of detecting not only the temperature of the electromotive force cell but the temperature of the pump cell by applying a current or voltage to the electromotive force cell are provided.

FIG.2



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